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THE EFFECT OF ALCOHOL ON HUMAN PERFORMANCE:

A CLASSIFICATION AND INTEGRATION OF RESEARCH FINDINGS

AMERICAN INSTITUTES FOR RESEARCH

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FINAL REPORT

Jerrold M. Levine
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THE EFFECT OF ALCOHOL ON HUMAN PERFORMANCE: A CLASSIFICATION AND INTEGRATION OF RESEARCH FINDINGS

SUMMARY

Because of the inconsistencies in the experimental procedures and approaches used by investigators, few generalizations regarding the influence of alcohol on performance can be advanced. An attempt is made to improve upon this situation in the present study by the application to the alcohol literature of a classification system or taxonomy of performance based upon human abilities.

The effort was designed, in part, to categorize the existing literature into task groups in order to determine whether alcohol effects differ as a function of different types of tasks. Tasks were grouped together on the basis of the abilities required to perform the task. A preliminary set of abilities was chosen representing the cognitive, sensory-perceptual, and psychomotor domains. Classifying studies with similar abilities into groups or domains permit relationships between alcohol and performance to be developed as a function of classes of tasks. While the primary classification is based upon human abilities, additional dimensions of classification were implemented so that research findings could be contrasted across such critical parameters as dosage and time.

The results indicated that the curves relating performance to dosage differed as a function of the ability requirements of the task. Further, the effects on performance of length of testing period and time between alcohol administration and the initiation of testing were marked and depended upon the abilities required by the task. In each case, different functional relationships were evident. Despite differences among the specific tasks in terms of displays, response requirements, performance index, technique of alcohol administration, etc., the categorization of tasks according to ability requirements enabled an integration of results and the development of functional relationships which otherwise were obscured.

THE EFFECT OF ALCOHOL ON HUMAN PERFORMANCE: A CLASSIFICATION AND INTEGRATION OF RESEARCH FINDINGS

INTRODUCTION

The need to make effective use of behavioral data generated by human performance research and application increases in its importance and scope as the body of human performance literature rapidly increases in size, variety, and complexity. What is required is a systematic structuring of this data so as to (a) integrate apparently disparate and isolated results, (b) improve generalizations across experimental studies, (c) identify gaps in the existing literature, and (d) identify new relationships among independent variables and performance. This is especially needed with regard to the effects of alcohol on human performance.

There is little question, for example, that alcohol affects aspects of job behavior. However, little is known about what aspects of job behavior and what specific kinds of tasks are most and least affected and under what dosages effects begin to appear. The present study seeks to make use of the available data on such questions by applying techniques developed in previous research. Specifically, a starting point for generalizing data about the effects of alcohol would be to identify the relationships between alcohol and performance which exist and to specify the gaps in our current knowledge. Reviews of the literature may provide some leads and are available (Jellinek & McFarland, 1940; Carpenter, 1962; Barry & Wallgren, 1970), but they do not effectively integrate the research findings. This is due to several characteristics of the literature which cause difficulty in any generalization or integration attempt. Some of these factors include:

1. Studies tend to differ in the type of control conditions used. Subjects may be used as their own control or there may be a separate control group. The former condition leads to results confounded by practice effects while the latter condition increases subject variability.
2. Important factors concerning the subject population are often not considered by the experimenter. These include sex, weight, age, and type of drinker (abstinent, moderate, heavy).
3. Experimenters differ on the dosage of alcohol administered. Ideally, dosage should depend on the body weight of each subject, but often it is administered as a fixed dose.
4. Studies tend to differ in terms of the type of alcohol used--straight ethyl alcohol, synthetic alcohol, vodka, bourbon, beer, wine, etc. Each

type has its own rate of absorption into the bloodstream and therefore may influence performance differentially.

5. Studies vary in terms of time allowed to consume the alcohol, time of day alcohol is ingested, and the time allowed to pass after drinking and before testing begins. These parameters are often uncontrolled and yet may markedly influence performance.
6. Studies are concerned with a wide variety of tasks with a wide range of dependent and independent variables. No consistent index of performance is used. This fact makes it very difficult to compare studies to one another.

Because of the inconsistencies in the experimental procedures and approaches used by investigators, few generalizations regarding the influence of alcohol on performance can be advanced. An attempt is made to improve upon this situation in the present study by the application to the alcohol literature of a classification system or taxonomy of performance based upon human abilities.

Our effort was designed, in part, to categorize the existing literature into task groups in order to determine whether alcohol effects differ as a function of different types of tasks. Tasks were grouped together on the basis of the abilities required to perform the task. A preliminary set of abilities was chosen representing the cognitive, sensory-perceptual, and psychomotor domains. Classifying studies with similar abilities into groups or domains should permit relationships between alcohol and performance to be developed as a function of classes of tasks. While our primary classification is based upon human abilities, additional dimensions of classification were implemented so that research findings could be contrasted across such critical parameters as dosage and time. In this fashion we have attempted to structure the literature by imposing upon it a multidimensional classification scheme. Results could then be interpreted both within and between categories in an attempt to develop relationships of performance to selected independent variables and to ascertain which of these relationships might generalize across categories. The literature on the effects of alcohol upon human performance might, in this fashion, be made more useful and suggest hypotheses which have previously been elusive to researchers.

Levine, Romashko, and Fleishman (1971) demonstrated the usefulness of organizing an area of literature on the basis of an abilities classification scheme. Vigilance, the chosen area, is rather precisely defined in terms of characteristics of the task situation and contains homogeneous tasks. Such homogeneity would lead one to anticipate little differentiation of task performance by categories of ability requirements. However, classifying tasks according to a small set of abilities did result in markedly different performance functions over time. By classifying tasks according to one of four primary abilities required for task performance, differential

relationships between performance and time in the vigil were produced. Furthermore, the impact of an independent variable on performance was found to be a function of the abilities required by the tasks.

A similar approach has been applied to the area of drug research. On the basis of the same general abilities classification "taxonomy" utilized in the vigilance study, a test battery was developed and the effects of specific dosages of a variety of drugs evaluated. Results indicated that for the drug scopolamine, for example, the same dosage of the drug affects different abilities differently in terms of: (a) the maximum effect obtained; (b) time to reach this maximum; and (c) time to recover. Had specific abilities not been used to evaluate these effects, such valuable information would have been lost. This study and subsequent investigations on other drugs such as caffeine (Baker & Theologus, 1972) and "stimulants" (Baker, Geist, & Fleishman, 1967), have verified the utility of the task classification approach in helping to generalize the effects of drugs on human performance.

A review of the effects of alcohol on human performance, presented in the following pages, indicated that alcohol has a depressant effect on all psychological functions. Much of the research is of limited value because of a lack of uniformity of procedure and scientific approach. Results are incomparable due to a failure by investigators to standardize factors which may influence the evaluation of the effects of alcohol on performance. Levine, Romashko, and Fleishman (1971) showed that structuring an area of literature on the basis of task requirements accounted for some of the variability of the data reported in the literature which previously was unaccounted for, and led to functional relationships hitherto unreported. The application of this approach to a broader, more heterogeneous content area, such as the effect of alcohol on human performance, was expected to lead to similar outcomes.

BACKGROUND

The effects of alcohol on human performance have usually been studied via brief tests under formal laboratory conditions. The majority of these studies have compared the performance of normal subjects receiving no treatment or a placebo with subjects who have been given a specified dosage of alcohol. In general, alcohol causes a depressant effect of the central nervous system functions which regulate sensory and motor performance, motivations, and emotions. Studies dealing with these effects are briefly reviewed below and have been thoroughly reviewed in the literature (Carpenter, 1962; Jellinek & McFarland, 1940; Wallgren & Barry, 1970).

Sensory Effects

Visual acuity, measured by tests of the ability to perceive correctly the differences in brightness which delineate shapes, seems to be relatively insensitive to the effects of alcohol. Marquis, Kelly, Miller, Gerard, and Rapoport (1957) found no effect of alcohol on visual acuity, but they gave only a small dosage (0.2 g/kg) to their 50 subjects. Colson (1940) and Brecher, Hartman, and Leonard (1955), giving alcohol every 1/2 hour until their subjects became incapacitated, found impairment in visual acuity only at high dosages and in a minority of the subjects. Such findings are consistent with those of Mortimer (1963) and Verriest and Laplasse (1965).

At high doses of alcohol, perception of dim lights may be slightly improved while there is a decrease in the ability to discriminate between lights of different intensities (Bernhard & Skoglund, 1941; Straub, 1957; Ikeda & Granger, 1963). There seems to be a resemblance between alcohol's effect on acuity and dark adaptation. Yudkin (1941) found improvements in dark adaptation after a small dose of alcohol (0.25 g/kg). In other studies no such beneficial effect was found, but this visual function was insensitive to detrimental effects except after high dosages (Blomberg & Wassen, 1959; Giardini, 1949). Resistance to glare, however, may be impaired by alcohol (Forster & Starck, 1959; Newman & Fletcher, 1941).

Studies of color perception have given evidence that alcohol causes the perceiver to become less sensitive to colors and relatively more sensitive to blue and green than to red hues. Schmidt and Bingel (1953) found an impairment in the discrimination of red, yellow, and green colors after approximately 0.7 g/kg alcohol. This finding is consistent with a study (Zeiner-Henriksen, 1927) showing that alcohol doses of 0.4 g/kg or above decreased discrimination of red, yellow, and green, but increased discrimination of blue, indigo, and violet hues.

In common with vision, audition seems to be resistant to the effects of alcohol on sensitivity, but more susceptible to the effects of alcohol on other aspects of perception. The ability to detect faint sounds is highly resistant to alcohol whereas discrimination among different sounds is more susceptible (Schwab & Ey, 1955) as is the ability to discriminate between pitches and rhythms (Pikhanen & Kauko, 1962).

In contrast to the high doses of alcohol generally required to impair visual or auditory sensitivity, rather low doses of the drug appear sufficient to decrease sensitivity to odors or taste (Irvin, Ahokas, & Goetzl, 1950; Margulies & Goetzl, 1950). And while alcohol has little effect on the sense of touch, it diminishes sensitivity to pain (Wolff, Hardy, & Goodell, 1942; Finkelstein, Alpern, & Gantt, 1945).

Sensori-motor Effects

Most performance tests require coordination between sensory input and motor output. Diverse tests have been used, differing in the particular sensory modality and motor skills required and in the complexity of the task. Variations in other respects, such as frequency of stimuli and duration of test, affect the degree of vigilance required and thus determine the susceptibility of performance to motivational factors.

Reaction time. One of the most frequently used tests to measure the effects of alcohol on sensori-motor performance is reaction time, where the subject is required to make a simple motor movement as quickly as possible after presentation of a visual or auditory signal. Results indicate that alcohol slows the speed of response, but only to a moderate degree at blood alcohol levels above 0.1%, with no consistent effect at lower blood alcohol levels. (Carpenter, 1962; Blum, Stern, & Melville, 1964; Boyd, Morken, & Hodge, 1962; Muller, Tarpey, Georgi, Mirone, & Rouke, 1964). There is some evidence that alcohol has less of a detrimental effect on response to a visual versus an auditory signal (Forbes, 1947; Carlson, Kleitman, Muehlberger, McLean, Gullicksen, & Carlson, 1934; Talland, 1966). On the other hand, increased difficulty of a task appears to enhance the detrimental effect of alcohol on response speed, such as in a complex discrimination task or when a subject's attention is occupied with a concurrent activity (Gruner, 1955; Carpenter, 1959).

Other tests of speed. Speed tests requiring sustained response to complex stimuli are more sensitive than reaction time to the effects of alcohol. As summarized by Jellinek and McFarland (1940, p. 321), five studies assessing the effects of alcohol on the Bourbon letter cancellation test showed that a dose of 0.4-1.4 g/kg caused a 5-27% decrease in performance. In 6 subsequent studies, alcohol doses of 1.0-1.4 g/kg decreased performance speed by 26-60% (Bohne, Luff, & Trautmann, 1957; Goldberg, 1943; Gruner, 1955; Gruner, 1959; Gruner & Ptasnik, 1953; Takala, Siro, & Toivainen, 1958).

A high degree of motor coordination is required in some tasks which are performed rapidly. According to Jellinek and McFarland (1940, p. 347), low doses of alcohol caused a large increase in typewriting errors, accompanied by a slight decrease in speed. Moderate doses of alcohol caused a sizable decrement in typing accuracy (Prag, 1953; Joyce, Edgecombe, Kennard, Weatherall, & Woods, 1959). Idestrom and Cadenius (1968), in tests of the effects of several doses of alcohol on various types of performance, found a relatively large increase in the number of errors in a task requiring continuous coordination of both hands in moving a stylus through a curved track. On the other hand, speed is only slightly impaired, even by rather high alcohol doses, in tasks with an emphasis on motor

dexterity rather than correct responses to complex stimuli (Muller et al., 1964; Lawton & Cahn, 1963; Takala et al., 1958; Rauschke, 1954).

Tracking and controlling objects in motion. In studies of sensori-motor coordination requiring adjustive responses by the arm or entire body, very low doses of alcohol are sufficient to impair the ability to track objects in motion, and errors are progressively increased by higher doses (Bahnsen & Vedel-Petersen, 1934; Drew, Colquhoun, & Long, 1958; Mortimer, 1963; Forney, Hughes, & Greatbatch, 1964; Hughes & Forney, 1964; Hughes, Forney, & Richards, 1965). A combined measure of tracking errors and reaction time to a signal, performed concurrently, also shows impairment under the influence of moderate alcohol doses (Newman & Fletcher, 1940; Loomis & West, 1958).

The tracking test resembles the performance of steering an automobile to keep it on the road at a safe distance from other moving vehicles. When the subject controls steering as well as speed, as in actual or simulated driving of a vehicle, the additional demand on the driver's attention and judgment appears to enhance the detrimental effect of alcohol. This increase in the complexity of the task appears to impair the steering capability of the driver (Aksnes, 1954; Chastain, 1961; Coldwell, Penner, Smith, Lucas, Rodgers, & Darroch, 1958). Driving speed is less consistently affected and may be decreased or increased by alcohol, depending on the test situation (Jansen, 1960; Coldwell et al., 1958; Huber, 1955).

Motor Effects

Motor behavior is controlled and influenced by sensory inputs as well as by various portions of the central nervous system, but alcohol effects have been tested on certain motor functions in which differential effects of sensory stimulation are minimized. Tests of voluntary motor control, measured by the subject's maximum ability to perform tasks which measure muscular steadiness show various magnitudes of depressant alcohol effects, with little evidence for stimulant or beneficial effects. Standing steadiness, measured by the Romberg test, is greatly impaired by alcohol (Carlson et al., 1934; Goldberg, 1943; Fregly, Bergstedt, & Graybiel, 1967). Laves (1955), in tests of 100 people accused of drunken driving, found that among those with blood alcohol levels of 0.10-0.15%, more than half swayed perceptibly in the Romberg test whereas less than 25% showed changes in any of his other measures of motor performance. The detrimental effect of alcohol was increased if the subject was required to stand with one foot placed in front of the other or to stand on one foot alone (Goldberg, 1943; Hebbelinck, 1963). When one foot was in front of the other, alcohol impaired steadiness by 1522% instead of 390% with the feet together in the experiment by Goldberg (1943). The relative effect of alcohol is enhanced when the eyes are open during the test. Begbie (1966) reported that a blood alcohol level averaging 0.06% increased swaying in tests with the eyes open but not in a test with the eyes closed.

Similar results have been reported on tests of hand steadiness (Newman & Newman, 1956; Marquis et al., 1957; Muller et al., 1964). On the other hand, measurements of motor control by walking have indicated that testing with the eyes open, thereby providing visual information, enabled

greater resistance to the effects of alcohol. Subjects performed better on this test with their eyes open than closed (Fregly et al., 1967).

Effects on Intellectual Functions

Verbal performance. Both the verbal and non-verbal components of standard intelligence tests have shown substantial detrimental effects of moderate or low alcohol doses in some experiments. Tests of verbal fluency, measured by quantity and quality of words elicited under certain conditions are sensitive to the influence of alcohol. Hartocollis and Johnson (1956) counted the number of words said in 3 minutes by 30 subjects under the influence of 0.7 g/kg alcohol compared with 30 control subjects. The alcohol subjects performed more poorly and showed increased repetitions of the same word during the test. Similar results have been found with larger amounts of alcohol (Repetun et al., 1960 as cited in Barry & Wallgren, 1970, p. 333).

Problem solving. Effects of alcohol on arithmetical calculations, such as addition, subtraction, and multiplication have been studied in a number of experiments. The results are variable but generally show a detrimental effect greater in measures of accuracy of performance than in speed.

Jellinek and McFarland (1940) concluded that addition of a series of numbers was generally impaired by a maximum of 15% (p. 356), with alcohol doses ranging from 0.3 to 0.9 g/kg. Frankenhaeuser, Myrsten, & Jarpe (1962) found 11% fewer multiplications by 8 subjects under the influence of 0.08% blood alcohol than in a placebo session. In a task requiring both addition and subtraction, Ekman, Frankenhaeuser, Goldberg, Bjerver, Jarpe, and Myrsten (1963) and Ekman, Frankenhaeuser, Goldberg, Hagdahl, and Myrsten (1964) found increased errors of from 15% to 31% with an increase in alcohol dosage from 0.33 to 0.66 g/kg.

The detrimental effect of alcohol is enhanced by certain types of task difficulty. In a serial addition task, requiring subjects to add cumulatively a series of numbers each presented at 1-second intervals, subjects receiving a dose of 0.12 g/kg alcohol made 37% more errors than a placebo group. Subjects receiving a dose of 0.25 g/kg alcohol scored 206% more errors than the placebo control (Blum et al., 1964). The necessity to attend to a periodic presentation of the numbers apparently enhanced the detrimental effect of alcohol on performance.

Tests under the distracting and stressful condition of delayed audio feedback have also been found to enhance the detrimental effect of alcohol on intellectual functions (Forney & Hughes, 1961; Forney & Hughes, 1964; Forney & Hughes, 1965; Hughes, Forney, & Gates, 1963; Hughes et al., 1965). Subjects were tested after drinking alcohol (0.5 g/kg) in one session and a placebo beverage in another session. The task comprised a series of tests of reading, counting, and arithmetic, requiring the subject to make verbal responses which were played back through earphones at slightly higher intensity and with a 0.28 second delay. The rather low dose of alcohol used in this series of studies impaired performance by an average of 31%. This decrement was greater than that found by other investigators under quiet testing conditions.

Several studies on the perceptual judgment of the passage of time suggest that alcohol slows the subjective process so that time seems to pass more quickly and the response designating an estimated time interval is made with a longer latency (Sterzinger, 1935; Wolff, Hardy, & Goodell, 1941; Hartocollis, 1962). Joerger (1960) reported that 0.5 g/kg caused prolongation by 82% the estimation of a "moment" of time.

Related to time estimation, Franks (1964) tested the frequency with which the relationship between perceived figure and background is reversed while the subject gazed at a "reversible figure" (Necker cube). He found that alcohol did not affect the spontaneously perceived reversal of figure and ground. When subjects were asked to inhibit the perceived reversal, the rate was decreased in the alcohol group but not in the placebo group. The apparent beneficial effect of alcohol on performance seems attributable to an increase in the subject's ability to fixate perception on a desired image.

Tests of more complex intellectual functions, requiring manipulation of verbal concepts according to rules of logic, have shown rather small but consistently detrimental effects of alcohol. In tests of logical thinking, including identification of errors in arithmetic terms and the ability to make deductions from syllogistic premises, alcohol tended to impair the performance of subjects (Nash, 1962). Similar results have been found when subjects were tested for abstract reasoning (Hutchison, Tuchtie, Gray, & Steinberg, 1964) and in an Inductive Reasoning test (Frankenhaeuser et al., 1962).

Learning and memory. Various aspects of learning and memory appear to be sensitive to the depressant effects of alcohol. The detrimental effect of alcohol on short-term memory might be attributable to impairment of the original learning, its retention, or of attentiveness at either stage (Barry & Wallgren, 1970). This is particularly true when the task requires reorganization of memorized materials by reciting words or digits backwards, such as in the Digit Span test (Buffard, 1959; Zirkle, McAtee, King, & Van Dyke, 1960; Hutchison et al., 1964; Nash, 1962).

Studies of long-term memory have indicated memory deficits in the sober condition for events and actions which occurred during intoxication (Wolff et al., 1941; Kalin, 1964). The phenomenon of "blackout" has been reproduced in the laboratory by Diethelm and Barr (1962) who reported that conversations and material learned while intoxicated were typically forgotten in the non-drug condition a day later. Retention appears to be better, however, in subjects tested under the same alcohol or non-drug condition as the original learning condition (Storm & Caird, 1967), suggesting that memory loss may be due to the effects of a change from drugged to sober condition, rather than to a specific detrimental effect of alcohol in the original learning.

Overview

An analysis of the total evidence of psychological investigations on experimentally induced alcohol intoxication reveals that alcohol has a depressing effect on all of the psychological functions measured. Even a

very brief acquaintance with the literature, however, brings out the fact that much of the experimentation is of limited value because of lack of uniformity of procedure and approach. The tendency has been for each investigator to set up a single problem with too little reference to the previous experience of other investigators. Results are incomparable due to the failure to standardize factors which may influence the effects of alcohol on performance. Such factors include: nature of control conditions, dosage, administration sequence, etc. Furthermore, the interpretability, comparability, and validity of experimental results is influenced not only by experimental conditions and procedures, but also by the adequacy of presentation and analyses of the data.

What is required is some kind of standardization by investigators and a better understanding of statistical procedures and the presentation of statistical data so that studies can be compared with one another and so that findings would have a greater degree of validity and reliability.

METHOD

Our approach toward integrating the literature on the effects of alcohol upon human performance focused on classifying diverse studies into similar groups on the basis of abilities required for task performance. A specific area of human performance (e.g., attention or memory) upon which to concentrate our efforts could not be isolated. There was no single area which contained a sufficient number of research studies to provide a large enough sample of data. As a result, it was necessary to consider many behavioral areas and therefore attempt to classify a markedly heterogeneous set of tasks.

Classification by Abilities

The abilities approach to task classification is based upon human abilities required for task performance. These general traits which enable an individual to perform different tasks are derived from factor analyses of human performance data. Thirty-seven abilities have been identified, operationally defined, and categorized into cognitive, psychomotor, perceptual-sensory, and physical domains.

The application of the ability classification system to a body of literature involves the determination of the extent to which an ability is required for task performance. A rater employs a 7-point task assessment scale, seven representing the maximum level of the ability, four a moderate level, and one the minimum level. In rating a particular task, two basic questions must be answered: (1) Is the ability required for performance, and (2) if so, to what extent? The ability ratings are then ranked in order to identify the most important ability for task performance. An arbitrary but rational criterion was established for the classification of a study into an ability category. The ability ranked highest in importance (the dominant ability) had to be rated at least "5" (between moderate and high on the scale) for inclusion of the study into that ability category. This criterion for selecting studies made it highly likely that the dominant ability was essential to task performance. Studies where the dominant ability was not rated 5 or above were not included in the ability category.

Selection of Abilities

Tasks requiring abilities falling into the cognitive, perceptual-sensory, and psychomotor domains were the most frequently occurring in the literature. Since few studies contained tasks involving abilities in the physical domain, this domain was ignored.

The heterogeneity of tasks in the literature resulted in the presence of many different dominant abilities across studies. The most frequently occurring were selective attention, perceptual speed, and control precision. These were selected as the basis for our classification. They are defined as follows:

- **Selective Attention:** This is the ability to perform a task in the presence of distracting stimulation external to the task or under monotonous conditions without significant loss in efficiency. Under conditions of distracting stimulation which can occur either within the same

sense or across senses, the ability involves concentration on the task being performed and filtering out of the distracting stimulation. When the task is performed under monotonous conditions, only concentration on the task being performed is involved. Selective attention is one of the abilities of the cognitive domain.

- **Perceptual Speed:** This ability involves the speed with which sensory patterns or configurations can be compared in order to determine identity or degree of similarity. Comparisons may be made either between successively or simultaneously presented patterns or configurations, or between remembered or standard configurations and presented configurations. The sensory patterns to be compared must occur within the same sense and not between senses. Perceptual speed is one of the abilities included in the perceptual-sensory domain.

- **Control Precision:** This is the ability to make controlled muscular movements necessary to adjust or position a machine or equipment control mechanism. The adjustments can be anticipatory motor movements in response to changes in the speed and/or direction of a moving object whose speed and direction are perfectly predictable. Control precision is an ability in the psychomotor domain.

Independent Variables

The choice of independent variables for analysis was based upon the frequency with which they were studied in the literature. The most common variables which were probably also the most important, were dosage and time.

All research studies dealt with dosage, although various indices were used. It was necessary to equate these indices in order to make comparisons across studies. The index g/kg body weight of absolute alcohol was selected for use because it was frequently reported and because it is a relative measure (i.e., it takes into account body weight and alcohol concentration). Blood alcohol level would have been an equally appropriate relative index but was not used since time of measurement often varied or was not given.

The manner in which dosage was administered also presented a problem. Three different types of dosage administration sequences were evident. Most studies were single-dose studies in which the experimenter administered the dosage of alcohol during a single, brief (<15 minutes) time before testing began. A smaller segment of the literature reported on multiple-dose studies. In these cases alcohol was administered at several points in time before testing began. The third and least frequent type of study was the maintenance-dose study. In these studies, alcohol was administered in a single dose before testing began and in additional supplemental doses during the testing session. Comparing the data from each of the three types of studies would not be appropriate as the differences in administration would tend to bias the results. Consequently, only single dose studies were chosen to be included in the data base.

Time was studied as an independent variable along three separate dimensions.

1. The time elapsing between the administration of alcohol and the

start of testing. Three levels were arbitrarily established for this variable; (a) ≤ 30 minutes, (b) 31-59 minutes, and (c) ≥ 60 minutes.

2. The time elapsing between the start and the completion of testing. Two levels were arbitrarily established for this variable; (a) ≤ 59 minutes, and (b) ≥ 60 minutes.

3. The time base along which performance measures were obtained (i.e., the time course of performance in the task).

Dependent Variable

The derivation of a common dependent variable was necessary in order to compare data across studies. However, due to the different behavioral areas represented in the literature, no single performance measure was available. The numerous reported dependent variables were, therefore, transformed into a relative performance measure which would be consistent across tasks.

The relative measure used was percent difference which was defined as the difference between the scores for the experimental and control conditions divided by the control condition score and multiplied by 100%. Positive values indicated superior performance by the experimental group. Negative values indicated that the alcohol-treated group was inferior to the untreated control group. Attempts to use accuracy and latency as more specific performance indices failed since there were too few studies employing these measures to permit evaluation.

Selection of Research Studies

An extensive search of the literature uncovered 179 studies dealing with the effects of alcohol on human performance. Each of these papers was carefully screened for inclusion in the data base. Criteria for study acceptance were: (1) an adequate description of the task, (2) a task which required abilities within one of the three ability domains (cognitive, sensory-perceptual, and psychomotor), (3) well-defined experimental and control populations, (4) sufficient and extractable performance data, (5) dosage or time as one of the independent variables studied, and (6) the administration of a single dosage.

Sixty-two studies (35%) were selected for further evaluation. Of the 117 eliminated, 18 were rejected because the task description was inadequate or the task involved physical abilities, 10 were rejected on the basis of inadequate controls, 68 were rejected for failure to present performance data, and 6 were rejected because they were not single-dose studies. In addition, 5 studies were eliminated because they were written in a foreign language, and 10 were eliminated because they were unavailable.

Data Extraction and Analysis

A comprehensive classification of the studies which satisfactorily passed the screening was accomplished. A literature abstracting form was used to extract and code all of the necessary and pertinent information

from each study. The literature abstracting form permitted the recording of the bibliographic citation, the report abstract, the independent variables, the dependent variables, the time course of the data, the dosage and other variables relating to the administration of alcohol, the control conditions, the subject population, the abilities required for task performance, the details of the task, the performance data, the significant results, specific significant comparisons, and main effect and interaction means.

A final review of the data base was carried out. The set of 62 acceptable studies was further reduced. Twenty-one studies were rejected because the reported dosage index could not be converted to g/kg Bw absolute alcohol. For the remaining studies, the dosage index either was or was converted to g/kg. These 41 studies constituted the final set. Many of these studies reported on several different experiments or used multiple tasks and provided data for each. As a result, the 41 studies generated 165 independent tasks.

RESULTS AND DISCUSSION

The 165 tasks were divided into categories on the basis of both dominant ability and domain. For each of these two categorizations, the tasks were further classified according to testing period and the time at which testing began. Mean percent difference was computed for each task at all levels of these independent variables. Median values across tasks within selected dosage ranges were computed and plotted. Functions were fit by eye to these data in order to determine whether relationships between performance and alcohol dosage could be differentiated as a function of (1) specific abilities required by the task, (2) ability domains, and (3) several parameters of time.

In certain cases, the curve drawn to fit the median data was somewhat arbitrary. Other equally good fitting functions could have been drawn. Some of the rules of thumb used for choosing the function presented were that the curve (1) be smooth and have only a single inflection point (if any) since it was not reasonable to expect performance to fluctuate with either increased dosage or time, (2) pass through the origin because at the time of alcohol ingestion and/or when alcohol dosage was zero, there was no reason to expect performance differences between experimental and control subject groups, (3) not seriously compromise or violate any data, and (4) be fit by considering the number of data points (tasks) going into each median value so that the greater the number of data points, the greater the impact of the median point on the specification of the curve.

In order to generate the plots of median performance, categories of dosage and time had to be established within which the mean performance data would be included for computation of a median value. For the dosage index g/kg, nine categories were selected lying between .20 and 1.00 in units of $.10 \pm .025$ (e.g., .175 to .225, .275 to .325, ..., .975 to 1.025). For the time index ten categories were chosen as 5, 10, 15, 30, 45, 60, 75, 90, 120, and 150 minutes. Mean scores falling outside of these categories did not enter into computation of the median value for that category with the exception that a median was computed and plotted for any discrete value within the overall index range but outside of any category if there were five or more mean scores available at that discrete value for the particular set of data under consideration. This was accomplished so as not to delete too much data from the median plots on the basis of a somewhat arbitrary categorization. All of the plots of medians conform to these rules.

The relative performance measure adopted for use was the difference between alcohol treatment condition and the no alcohol treatment condition scores divided by the no alcohol treatment condition score. This term was multiplied by 100% to give the relative index of performance, percent difference. Positive scores indicate that the alcohol treated group performed better than the no alcohol control. Negative scores indicate that the alcohol group was inferior to the control group. The magnitude of the score indicates by what amount the two groups differed.

Earlier, we discussed our choice of g/kg as a dosage index. Studies reporting both g/kg and BAL were used to correlate the measures. The

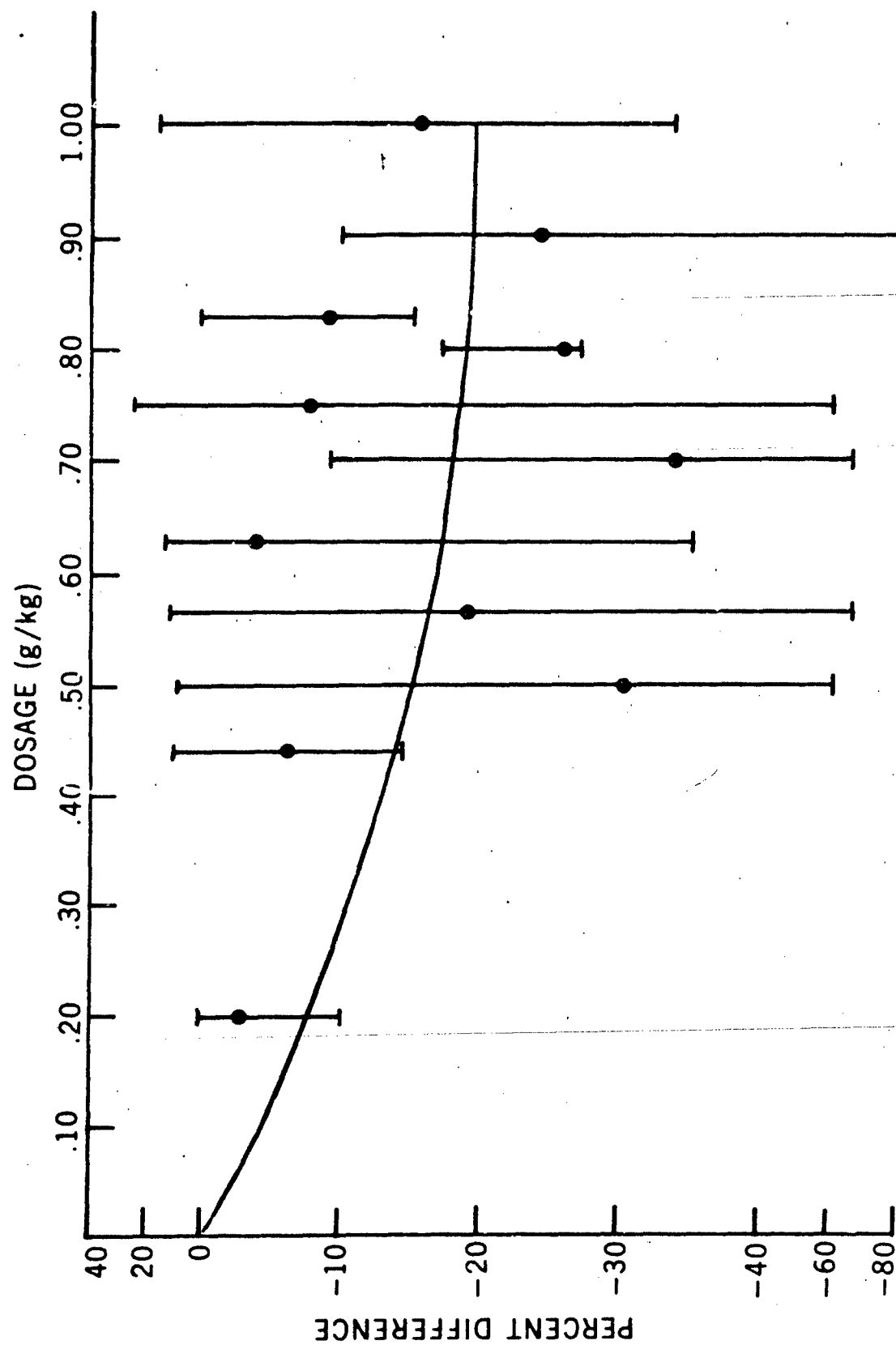


Figure 1. Median percent difference as a function of dosage

Pearson product-moment correlation coefficient was .77 ($N = 151$, $p < .001$), suggesting that the results to be reported would be consistent with those obtained had BAL been used as a dosage index.

Categorization of Tasks

The 165 tasks identified from the 41 studies selected for evaluation all manipulated dosage as an independent variable. Only 14 of 165 (9%), however, manipulated time by measuring performance at specified intervals during the course of the task. A total of 224 indices of performance were used since many tasks permitted the measurement of more than one kind of performance. However, only 5% of the 165 tasks measured or reported accuracy and only 23% measured or reported latency. These two very common performance indices are relatively sparse in the literature evaluated.

The classification of tasks into ability domains resulted in 60% falling into the cognitive domain, 24% into the perceptual-sensory domain, and 16% into the psychomotor domain. In terms of specific abilities, 44% of the tasks were classified as requiring selective attention as its predominant ability, 10% as requiring perceptual speed, and 5% as requiring control precision.

Tasks were also classified in terms of when testing began and how long it lasted. Of the 165 tasks, 25% began testing within 30 minutes of administering alcohol, 66% waited 60 minutes or more before initiating testing, and the remaining 9% began testing more than 30 but less than 60 minutes after alcohol was administered. Of the tasks reporting information on length of testing period, 78% lasted less than one hour and the remainder one hour or longer.

The results to be reported are presented below in Figures 1 through 8. In each of these figures, performance is represented by median percent difference. In nearly all of these figures the performance medians are negative values indicating that alcohol treated groups performed more poorly than non-alcohol treated groups. In the first seven of these figures performance is plotted as a function of dosage measured in g/kg absolute alcohol. In Figure 8 the abscissa changes to time.

Figure 1 depicts overall performance as a function of dosage. The function fitted by eye to these data suggests that alcohol impairs performance and that the amount of impairment increases with increased dosage up to approximately 1.0 g/kg absolute alcohol. There is a suggestion that beyond this dosage the amount of impairment asymptotes. The range of values associated with each median point in Figure 1 is also indicated. It can be seen that performance differences were as much as 75-80% between the experimental and control conditions. The average amount of impairment appears to be approximately 20% at asymptote. There were a few instances in which the alcohol treated group performed better than the non-alcohol treated group as indicated by certain of the ranges having positive values on the graph.

Classification by Domains and Abilities

With the data of Figure 1 as a starting point, more fine-grained analyses of performance as a function of alcohol dosage were carried out. Figure 2 shows one such analysis where the relationship between performance and dosage has been plotted with ability domain as a parameter. The three functions represent data from tasks in which the dominant ability was in the cognitive, perceptual-sensory, or psychomotor domain. All three functions are practically identical and correspond to the overall relationship depicted in Figure 1. The major difference among the functions in Figure 2 appears to be the point at which performance deterioration asymptotes. The data here suggest that psychomotor tasks are least impaired by alcohol and that perceptual-sensory tasks are most impaired by alcohol. Cognitive tasks fall in-between. This statement holds true with regard to both the rate of performance deterioration as dosage increases and the amount of performance deterioration at asymptote. It is worth noting that the differences between these functions are fairly small and the differences in asymptotic levels are only about 15%. For all three functions, performance deterioration asymptotes at approximately .80 g/kg.

Since psychomotor tasks tend to be highly learned, they might, therefore, be most resistant to performance deterioration under the influence of alcohol. Cognitive and perceptual types of tasks ordinarily do not tend to be overlearned and perhaps, therefore, show a greater deterioration.

Figure 3 depicts performance as a function of dosage with ability categories as a parameter. The data of Figure 2 were further broken down so as to include tasks which were classified into the ability categories of selective attention, perceptual speed, and control precision. The number of data points here is small and therefore conclusions and interpretations must be made with caution. There is a striking similarity between perceptual speed and control precision tasks in terms of their rate of performance deterioration and their asymptote. There is only a 10% difference between alcohol and non-alcohol treated groups. There is little or no difference between tasks involving the abilities of perceptual speed and control precision in terms of the relationship of dosage to performance.

This situation is somewhat different, however, for tasks involving selective attention. The data suggest that performance on tasks involving this cognitive ability is seriously impaired. Moderate dosages cause marked performance impairment (up to 40% degradation). Figure 3 also substantiates the suggestion in Figure 2 that the effect of alcohol on performance depends in part upon the task being performed and more specifically upon the abilities required for successful task performance.

Classification by Abilities and Time Variables

Figures 4 and 5 show performance as a function of dosage when studies are classified according to length of testing. Figure 4 presents these data categorized according to ability domains. Figure 5 presents corresponding data categorized according to specific abilities. Figure 4 suggests a clear-cut difference between testing periods of 59 minutes or less

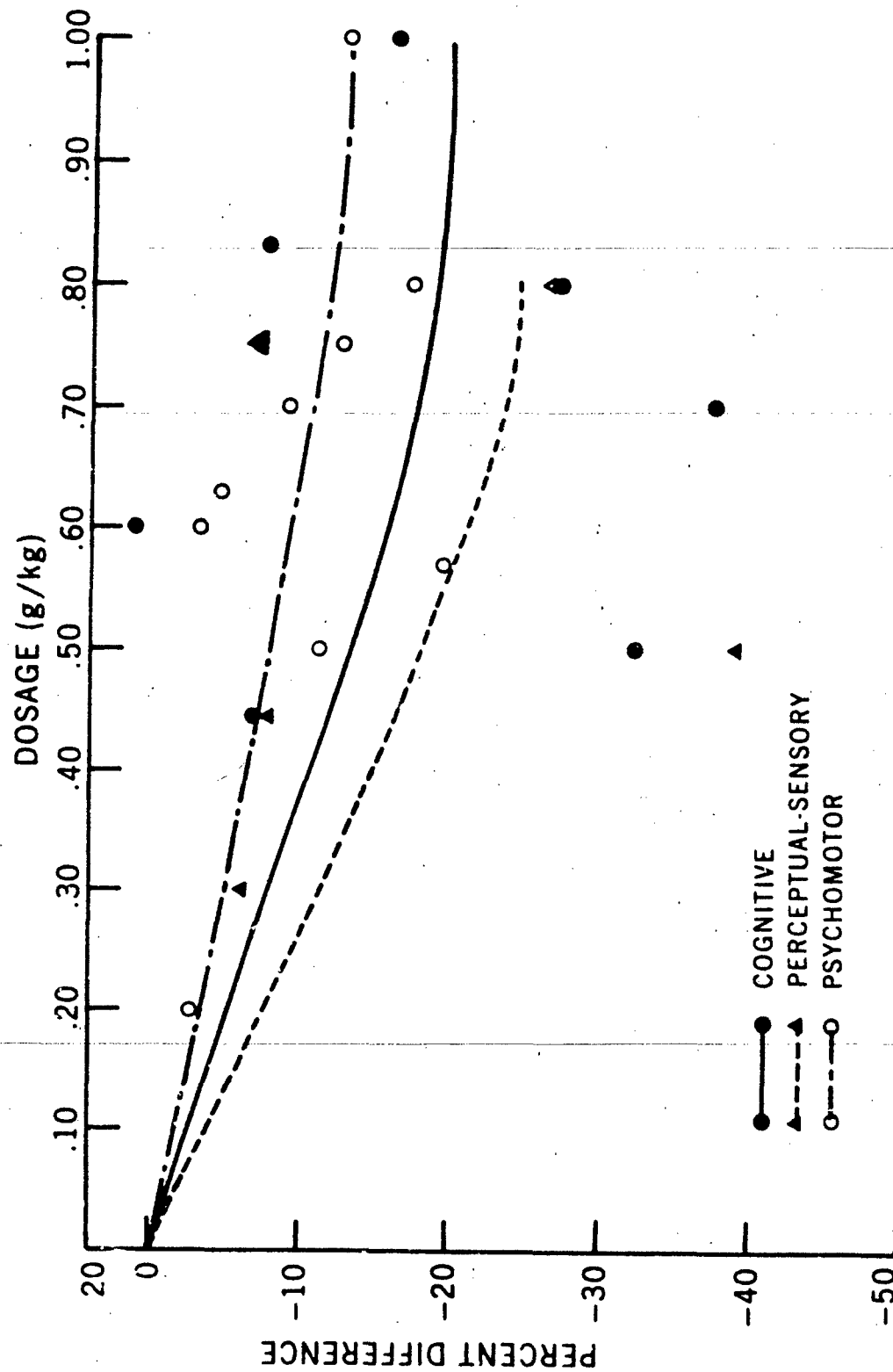


Figure 2. Median percent difference as a function of dosage and ability domain

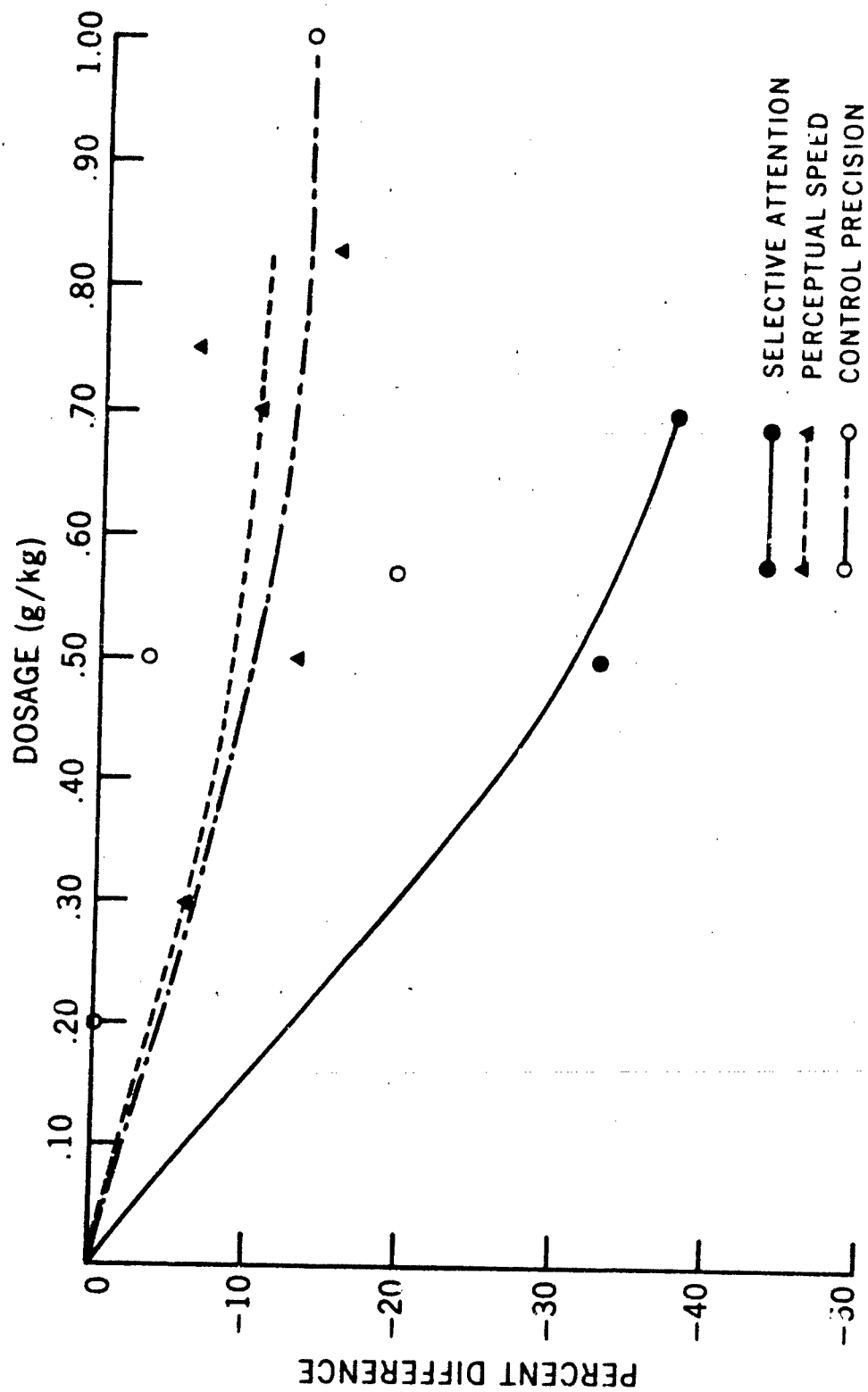


Figure 3. Median percent difference as a function of dosage and predominant ability

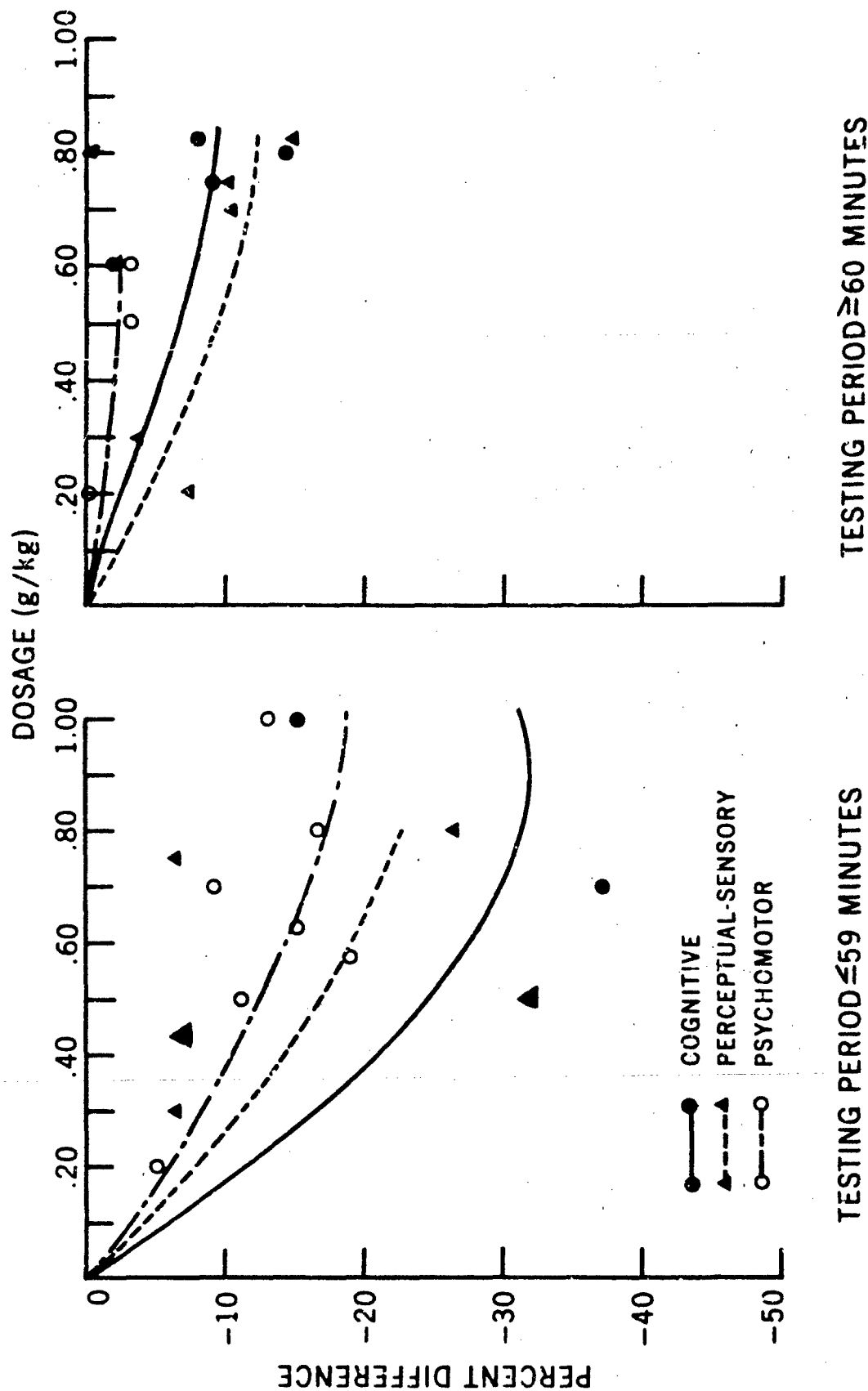


Figure 4. Median percent difference as a function of dosage and ability domain for each condition of length of testing

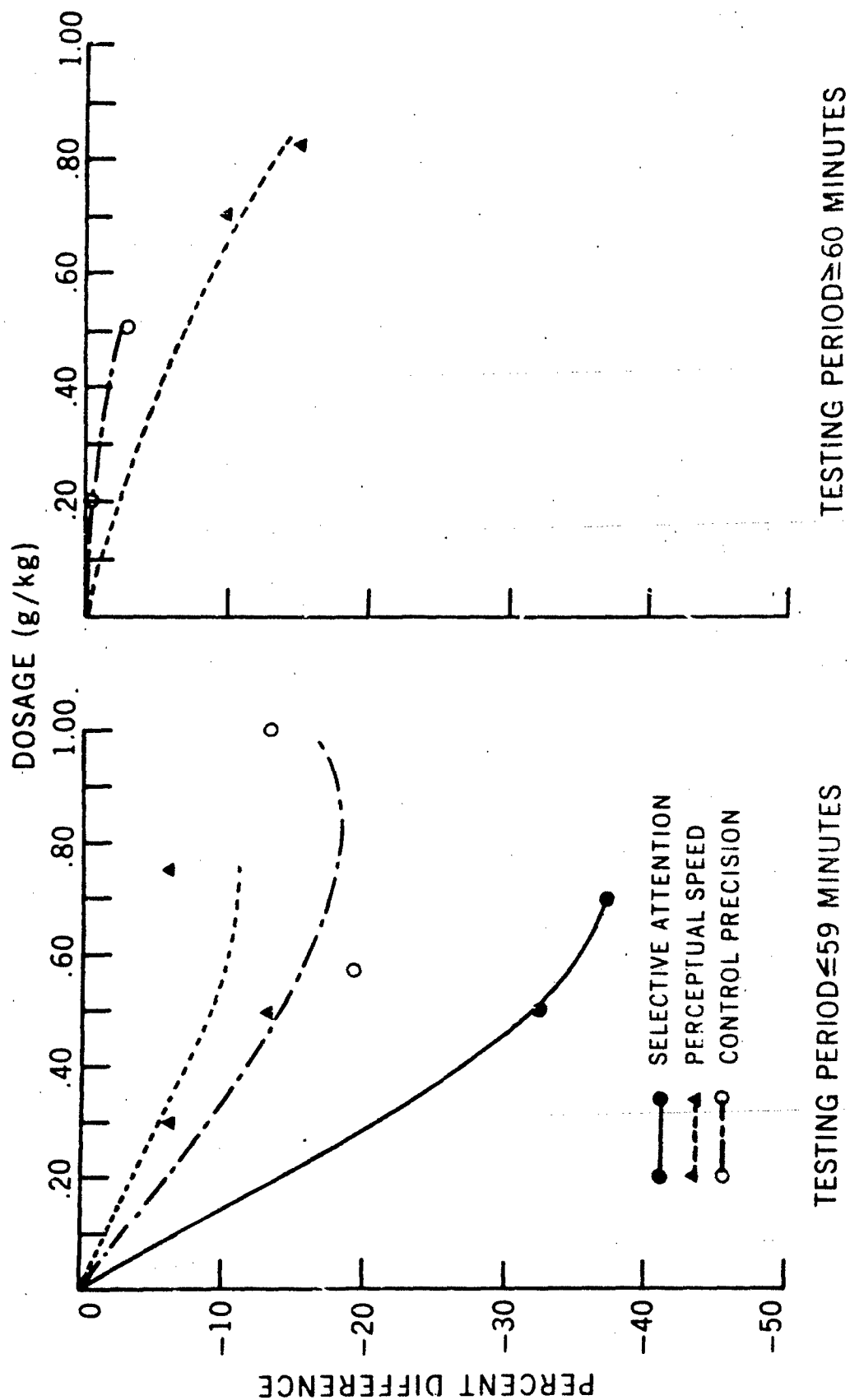


Figure 5. Median percent difference as a function of dosage and predominant ability for each condition of length of testing

and those of 60 minutes or more. In both cases there is a performance deterioration with increasing dosage and this holds for each of the three ability domains plotted. But the rate of deterioration and the average amount of deterioration appears to be much greater when testing periods are 59 minutes or less than when they are an hour or more. For the shorter testing period the greatest performance deterioration occurs in cognitive tasks; whereas, for the longer testing period the greater deterioration occurs in perceptual-sensory tasks. These findings point up the need to consider length of testing period as a critical parameter in trying to describe and generalize relationships between performance and alcohol dosage.

Figure 5 is based upon a small amount of data but the conclusions that can be drawn from it are similar to those in Figure 4. In fact, the difference between testing periods becomes even more apparent in Figure 5 than in Figure 4 when performance is plotted for tasks involving the particular abilities of selective attention, perceptual speed, and control precision.

Figures 6 and 7 show performance as a function of dosage for different times of initiating testing. The data were divided into categories based on the elapsed time from the administration of the alcohol dosage to the initiation of testing. The categories used were less than or equal to 30 minutes, 31-59 minutes, and equal to or greater than 60 minutes. Figure 6 shows these functions for the three ability domains; cognitive, perceptual-sensory, and psychomotor. Figure 7 shows these functions for tasks involving the specific abilities of selective attention, perceptual speed, and control precision.

Figure 6 suggests that the greatest impact of alcohol upon performance occurs when an hour or more is permitted to elapse between the administration of alcohol and the initiation of testing. Further, when these conditions prevail, it is the cognitive and perceptual-sensory tasks which are most hampered by alcohol; the psychomotor tasks seem to be more resistant to the effect of alcohol. When testing is initiated within 30 minutes of alcohol administration, the impact of alcohol appears to be minimized as shown in the left most portion of Figure 6. Here there is little differentiation between the functions relating performance to dosage for the three ability domains. Figure 7 supports these findings for specific abilities.

Figures 4-7, taken together, clearly demonstrate the differences in the relationship of alcohol dosage to performance as a function of both task requirements and parameters of time. Few studies in the literature manipulated either testing period or the time between the administration of alcohol and the initiation of testing as independent variables. Yet, the data of Figures 4-7 indicate these variables to be an influential factor in determining the impact of alcohol upon performance. Doubtless, there are other variables which have an equal or greater influence on the function relating dosage to performance and which have also been neglected in the literature.

Contrasting Figures 4 and 6 suggests that the length of the testing period has a greater impact upon the relationship between dosage and performance than does the elapsed time between dosage administration and testing.

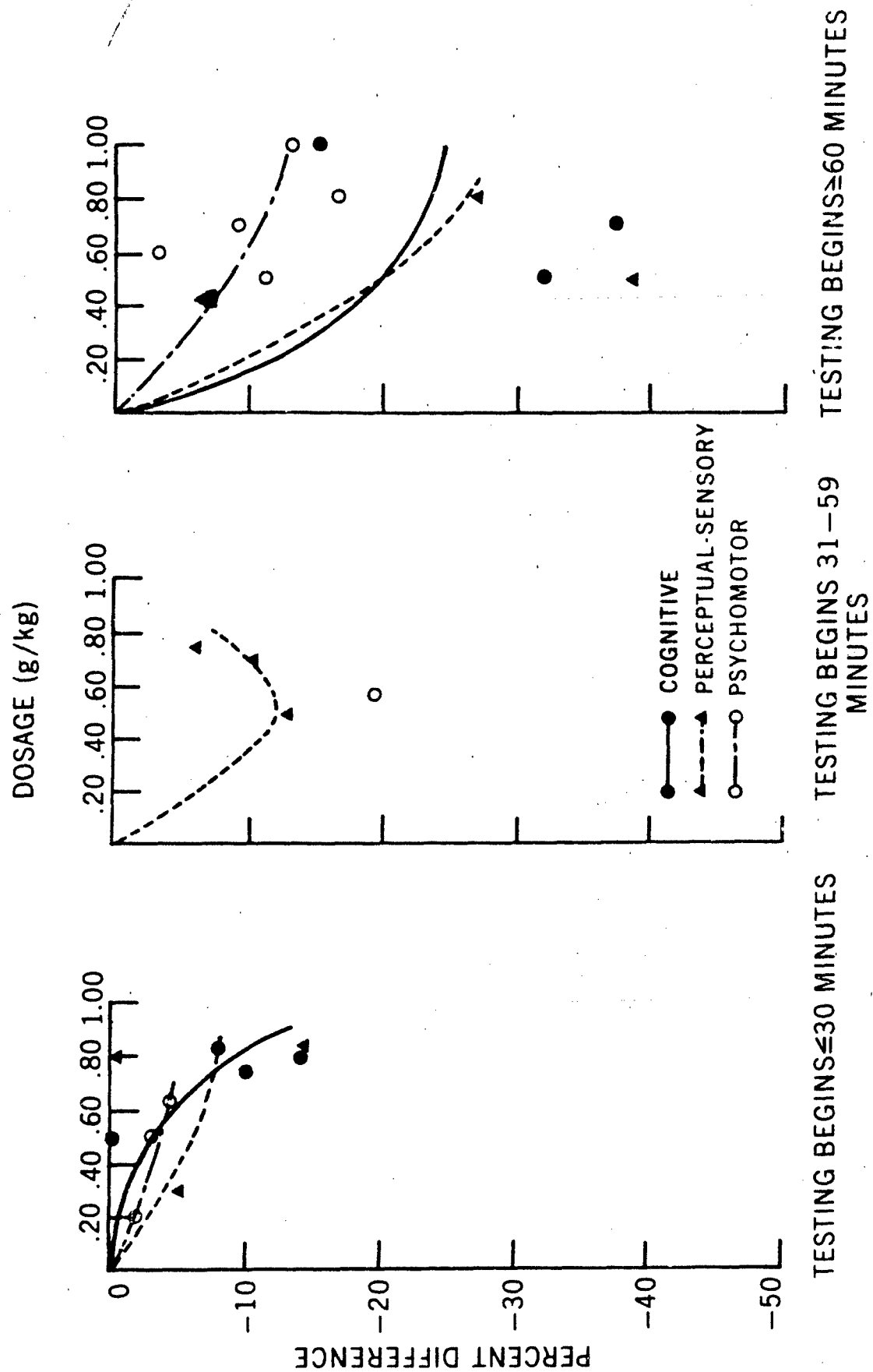


Figure 6. Median percent difference as a function of dosage and ability domain for each condition of time at which testing begins

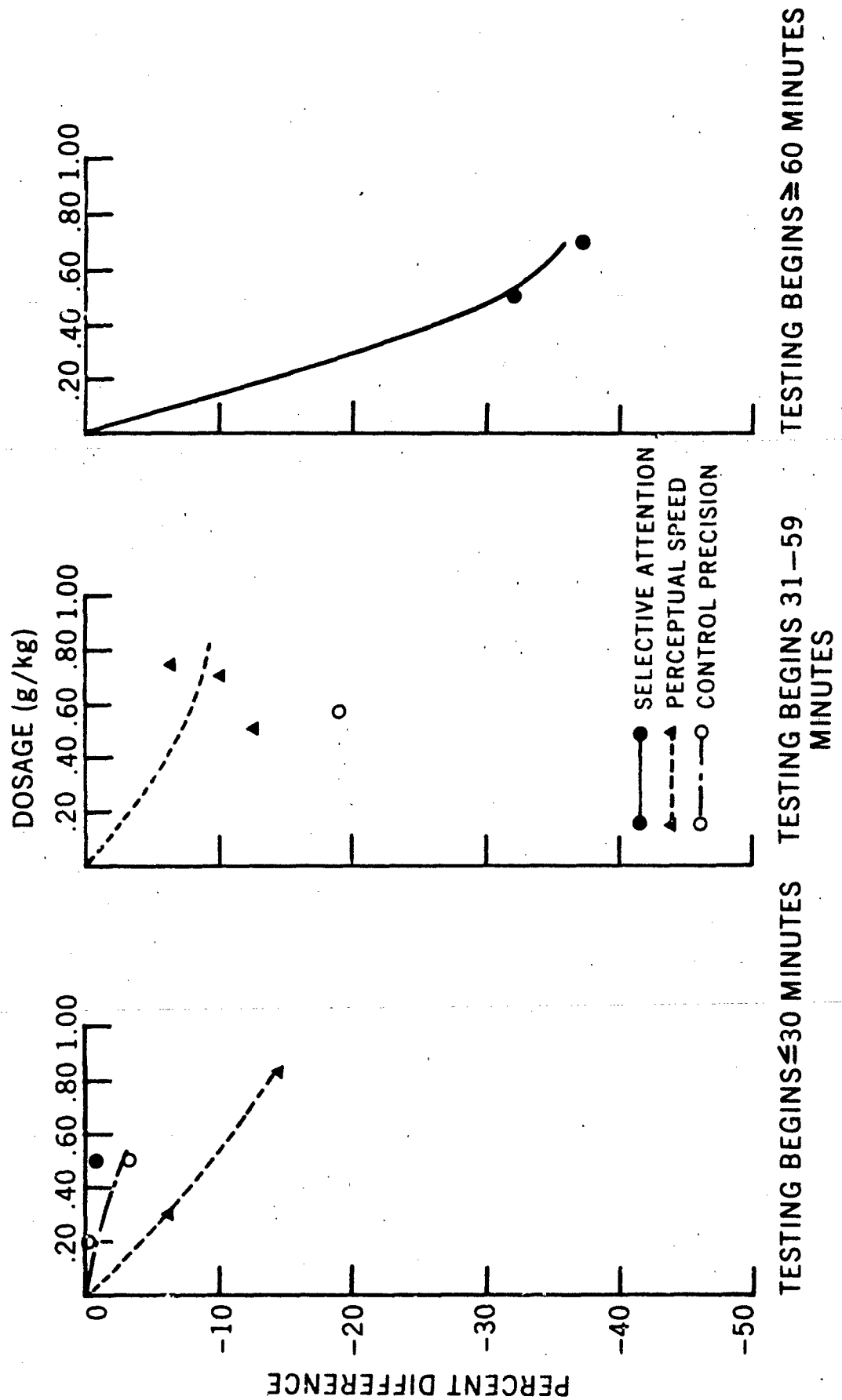


Figure 7. Median percent difference as a function of dosage and predominant ability for each condition of time at which testing begins

Figure 8 depicts performance as measured in median percent difference between alcohol and non-alcohol treated groups as a function of time in the task. Tasks falling into the cognitive, perceptual-sensory, and psychomotor domains are plotted separately. Each function represents a particular dosage category. The time course of performance differs with respect to the nature of the task involved. In fact, for psychomotor tasks there appears to be an improvement in performance with time under conditions of fairly high alcohol dosage. Except for this single situation, the other functions suggest that performance deteriorates with time in the task for all levels of alcohol dosage and for all kinds of tasks. The rate and degree of deterioration, however, are a function of both dosage levels and task categories. It is important to note that greater deterioration did not necessarily occur with time when the dosage was highest. For both perceptual-sensory tasks and psychomotor tasks, dosages in the range of .68 to .85 g/kg resulted in poorer performance with time than did a dosage level of greater than .85 g/kg. Thus, in terms of the time course of performance under the influence of alcohol, these data do not substantiate the generalization that increasing the dosage increasingly impairs performance.

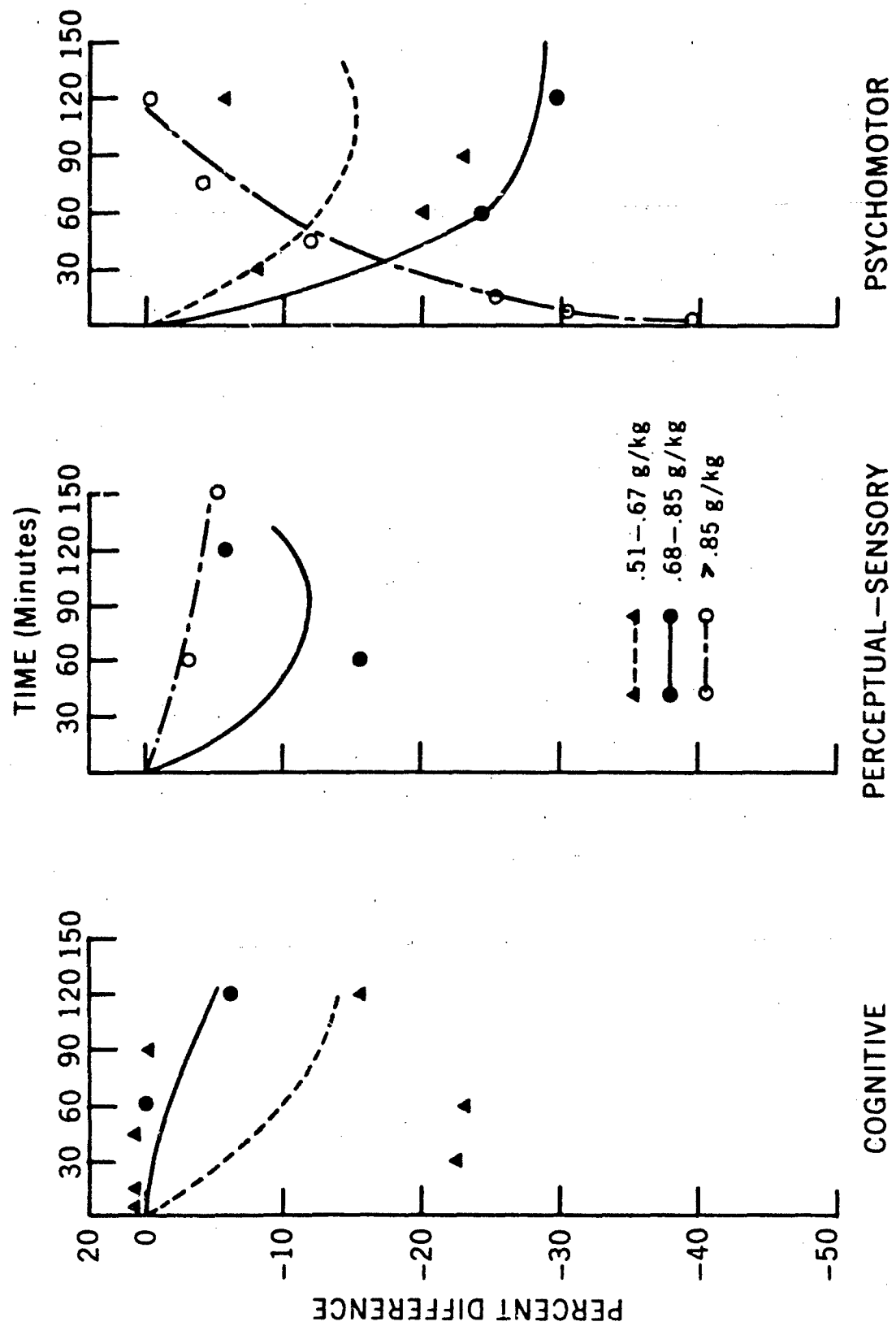


Figure 8. Median percent difference as a function of time in the task and categories of dosage

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

The data suggest that the curves relating performance to dosage differ as a function of the ability requirements of the task. Further, the effects on performance of length of testing period and time between alcohol administration and the initiation of testing were marked and depended upon the abilities required by the task. In each case, different functional relationships were evident. Overall, psychomotor tasks appeared to be least impaired by alcohol and perceptual-sensory tasks appeared to be most impaired. Cognitive tasks fell in-between. Performance deteriorated more rapidly and was impaired to a greater degree when the testing period was less than one hour than when it was one hour or greater. Further, cognitive tasks were most impaired in shorter testing periods but perceptual-sensory tasks were most impaired in longer testing periods. The greatest impact of alcohol upon performance occurred when an hour or more was permitted to elapse between the administration of alcohol and the initiation of testing. Further, it was the cognitive and perceptual-sensory tasks which were most hampered by alcohol; the psychomotor tasks seemed to be more resistant to the effect of alcohol. When testing was initiated within 30 minutes of alcohol administration, the impact of alcohol appeared to be minimized.

Despite differences among the specific tasks in terms of displays, response requirements, performance index, technique of alcohol administration, etc., the categorization of tasks according to ability requirements enabled an integration of results and the development of functional relationships which otherwise were obscured.

It must be emphasized that the relationships depicted in Figures 1-8 are to be viewed as preliminary findings. The relationships must be validated through research. Nevertheless these functions are the basis for a great deal of future research on the effects of alcohol upon human performance. Several important directions for future research are discussed below.

1. Too often, alcohol research has been carried out on behavior which is of little theoretical or practical significance. The results of such experiments do not add to the base of knowledge on the effects of alcohol on performance. Research should be concentrated on tasks which tap some underlying behavioral mechanism, such as attention, memory, etc., and which simulate aspects of performance which are commonly required in real-life situations.
2. One of the difficulties in alcohol research is the question of how to handle practice effects. Jellinek and McFarland (1940) discussed this problem at great length and cautioned that practice was an influential factor in the evaluation of the effects of alcohol. Practice can be controlled for experimentally or results can be adjusted statistically in order to eliminate its influence. The problem is that many studies fail to do either. As a result, the findings

on the effects of alcohol are frequently confounded and therefore inconclusive. Practice effects must be dealt with carefully and appropriately in the design stage of research in order to ensure valid results. While there has been a great deal of ignoring, minimizing, eliminating, adjusting, and controlling for practice effects, there appears to be no studies concerned with the extent to which alcohol affects the practice curve (acquisition). Pre-asymptotic performance is usually not studied, despite the fact that it would enable more precise statements about the effect of alcohol on performance.

3. The present effort points to the influence of time parameters in the effect of alcohol on performance. Both the length of testing and the elapsed time between dosage administration and the initiation of testing affected the relationship between performance and dosage. Yet, rarely have these parameters been manipulated as independent variables in studying alcohol's effect upon performance. Such research should be accomplished.
4. Time as a variable continues to be neglected in alcohol research. We recommend that efforts be undertaken to evaluate the time course of performance after an initial single dose of alcohol, the time course of performance as a particular dosage level is maintained, and most importantly, the interaction of dosage and time upon performance. The effect of alcohol upon performance is obviously and critically time-dependent, but little is known about this dependency.
5. Most research on the effect of alcohol upon performance has considered a non-alcoholic subject population. But, the performance implications of alcohol must also be evaluated for alcoholics since alcohol-dependency is so widespread in our society. We must determine, for the alcoholic, which aspects of performance are impaired by alcohol and which are not. Further, we must assess how performance is affected as a function of the length of time the individual has been alcohol-dependent since the effects of alcohol on the moderate or heavy drinker and on the alcohol-dependent person are, in some respects, very different.
6. Reviews of the literature by Jellinek and McFarland (1940), Carpenter (1962), and Wallgren and Barry (1970) call for standardization of research methodology in studying the effects of alcohol. The goal is to standardize subject populations, dosage administration technique, dosage index, type of alcohol, etc., in order to make findings more comparable to

one-another. A sometimes neglected but very important consideration is the need to employ indices of performance which are commonly used in psychological research. Two such indices are accuracy and speed of performance. Of the studies included in this effort, only 5% reported accuracy scores and only 23% reported latency. Future research would be more useful if these indices were more frequently used.

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APPENDIX I

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APPENDIX II

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APPENDIX III

LITERATURE ABSTRACTING FORM

LITERATURE ABSTRACTING FORM

1. Complete Reference

2. Independent Variables

<u>Name</u>	<u># Levels</u>	<u>Specification of Levels</u>
(a) Dosage		
(b) Time		
(c)		
(d)		
(e)		

3. Performance Measures

<u>Name</u>	<u>Operational Definition</u>
(a)	
(b)	
(c)	

4. Time Course of Data Every K Minutes/Hours

5. Dosage Determination and Index

6. Control Conditions

7. Subject Population

8. Abilities Involved

	<u>Domain</u>	<u>Ability</u>	<u>Degree</u>	<u>Rank</u>
(a)				
(b)				
(c)				
(d)				
(e)				

9. Task Description Details

-
11. Data (For each performance index, record the means at every combination of experimental conditions given in the documents. Also list statistically reliable effects, and statistic used.)

A. Effects Listing

Source

Significance

Specific Comparison & Notes

B. Performance Matrices for Main Effects and Interactions

12. Critique of Article (especially methodology)

DOSAGE INDEX	DOSAGE LEVELS				NOTES
g/Kg					-----
g/Kg absolute alcohol					-----
g					-----
BAL					-----
Qualitative					-----

Type of Study

Single Dose Study

Multiple Dose Study

Maintenance Dose Study

Testing Begins
 ≤30 min 31-59 min ≥60 min

≤15 min

16-59 min

≥60 min

Testing Period

